

International Steering Committee for Transport Survey Conferences

# Using eye track devices to understand individual decisions process in stated preferences experiments: an application to the choice of electric vehicles

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## Abstract

In this paper we discuss the use of eye tracking technology to explore how individuals process information in a stated preference experiment. With the aim to add some evidences to a very short literature, we dig deeper into the analysis of the visual attention measures to discuss the heterogeneity of the visual process across participants, the attendance of attributes, the visual attention paid and potential trade-offs revealed by the consecutive fixations of pairs of attributes. Our results reinforce the evidence of significant heterogeneity in the individual's visual process, and suggest that the analysis of the sequence of the information fixated can help understanding the decision process.

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## 1. Introduction

A persistent problem in using Stated Preference (SP) methods is that respondents often adopt decision processes that deviate from the assumption that individuals evaluate all the attributes presented in a compensatory way. As recently summarized by Cherchi and Hensher (2015) when respondents are “presented with a complex task, it is likely that they show disengagement, adopting simplifying strategies to reduce the mental effort required solving the

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problem. On the other hand, simplified survey tasks can be seemingly perceived as unrealistic by the respondents, leading to problems with respondents' engagement, or respondents choosing based on other attributes not included in the design." A growing literature on stated choice experiments has focused on the problem of attribute non-attendance (ANA), i.e. when individuals ignore some of the attributes presented. Evidences, mainly based on model estimation results, show that the number of attributes and their levels but also the importance and relevancy of attributes presented potentially determine the attribute processing strategies adopted by a respondent. If one attribute is much less important than the others or its levels do not vary over a range that matters enough to result in a trade-off for the respondent, the attribute can be excluded from the decision process.

In the attempt to improve the knowledge on how individuals make decision, researchers have recently tried to use eye tracking technology to identify which information respondents pay (visual) attention to. This is a promising area of research, but, at the moment, there are very few studies that used eye tracking technology in a stated preference experiment. These mostly look at different effect of visual attention on the decision process and, when they look at the same effect, evidences are often in opposite direction. Balcombe et al, (2015), Krucien et al. (2014) and Cherchi and Raja (2016) focused on the attributes non-attendance. Balcombe et al, (2015) in a food context investigated the role of stated and visual attendance in explaining ANA. Using a sample of 40 respondents, each presented with 12 tasks, they didn't find any substantial evidence that looking at an attribute for a longer period of time, or more often, necessarily gives that attribute a high value or importance. Krucien et al. (2014), instead, in an application on health economics, used as measure of visual attention the time respondents spent looking at an object instead of the duration of eye fixations. Using a sample of 28 students of psychology, each presented with 11 tasks, they found that increased visual attendance decreases the model variance. Cherchi and Raja (2016) is the only work in a transport context. Using a sample of 19 respondents working or studying at the University, they found that stated and visual ANA are poor predictors of each other, but the inclusion of the fixation time in the model specification improves slightly the model estimates. There are a couple of other work that studied the role of visual attention during SP experiments, but do not focus on ANA. In particular, Yang et al., (2015) found that estimating consumer preferences based on choice and information processing data (as opposed to choice data only) gives rise to improved out-of-sample predictions. Uggeldahl et al. (2016), in a context of food choice, investigated if the number of times that respondents shift their visual attention between the alternatives in a choice set reflects their stated choice certainty. Using 193 respondents recruited at the Copenhagen Business School, their models results confirmed that the frequency of the eyes shift between alternatives is related to the stated choice (un)certainty and can be used to explain systematic variations in the error variance. Finally, Meißner et al (2016), using 60 respondents, answering 12 choice tasks, presented mostly with images, found a positive correlation between the importance of an attribute and the attention paid. They also found that the reliability of the choice made increases with the tasks, though the time spent decreases.

With this work, we aim to add some evidences to the above short literature on the role of visual attention to reveal individual decision process. Differently from the previous works, we will focus more on understanding the individual decision process that is revealed from the eye tracker measures, rather than on the role of these eye tracker measures in the model estimation. Using a sample of 30 respondents, we will then dig deeper into the analysis of the visual attention measures to discuss the heterogeneity of the visual process across participants, the attendance of attributes and the visual attention paid to them. We will then analyse and compare different measures of visual attention, namely the number and duration of fixations, the number and duration of the visual attention and the transitions between attributes. We also compare our results with those of Cherchi and Raja (2016) that used a similar SP experiment. Finally, the impact of the visual attention measures on the estimation of the individual preferences will be discussed.

The rest of the paper is organised as follows: in Section 2 we briefly describe the use of eye tracking devices to measure visual attention and the metrics that can be computed to measure visual cognition. In Section 3, we describe the experiment carried out, while Section 4 reports a discussion of the analyses conducted. Section 5 summarises our conclusions.

## 2. Visual cognition and eye tracker

The eye tracker is a device that registers the position and movement of the eyes. Eye movements are a window into the human cognitive process (Koop and Johnson, 2011; Gidlöf et al, 2014; Itthipuripat, et al., 2015), hence the eye

tracker is potentially relevant for those studies that aim to estimate individual preferences based on specific assumptions on how people take decision.

Regular eye movement alternates between saccades and visual fixations. A fixation is the maintaining of the visual gaze on a single location for a certain duration. A saccade instead is a quick, concurrent movement of eyes between two phases of fixation in the same direction. Analogously the fixation can be seen as the point between any two saccades, during which the eyes are relatively stationary and virtually all visual inputs occur.

The fixation is the most direct measure of the visual attention paid to specific information, while the saccades are considered the most important eye movement when it comes to the search process while visualising an object. It was initially believed that during saccades sensitivity to visual input is reduced and no information is processed (Matin, 1974). However some recent studies demonstrated that some cognitive process, and in particular the lexical process, is not suppressed during the saccadic eye movement. Duchowski (2007) studied eye tracking in detail and concluded that though it can be considered that brain may be blind during the saccadic movements (no cognitive thinking occurs), saccades are related to search process.

In practical studies, in order to identify the visual attention related to specific information, the displayed stimulus (the SP task in our case) need to be divided into sub-regions, called areas of interest (AOI). The visual attention metrics will then be computed for each AOI. When the stimulus is a SP experiment, the identification of AOI is relatively straightforward, as attributes are typically presented in format of matrix. However, it is still important to pay attention to the format of the stimulus in order to ensure that the information presented are well apart, as this improves precision in the measurement of the visual attention.

As discussed previously, all previous studies have used as metric for the visual attention, the number and duration of fixations, which means how many time and for how long a respondents has fixated a particular AOI. Other metrics can be extract that can be relevant to explain individual decision process. These are the number of visits in each AOI, i.e. how many time a given AOI is revisited and how long for. Each visit to the same AOI can and typically does include more than one fixations. The number of visits is always smaller than or at least equal to the number of fixations. Finally, another interesting measure that can be computed is the transitions, i.e. the number of times a pair of AOI is looked at consecutively, as this reveals potential trade-offs between pairs of attributes. In this study, other than the number of fixations and their duration, as in the previous studies, we also analyse the number of visits and their duration, and the number of transitions.

Although fixations are generally linked to cognition process, it is demonstrated that an information needs to be fixate for a certain amount of time in order for the stimulus to arrive to the brain and to be elaborated. This minimum amount of time is typically assumed to be 100ms, hence typically fixations shorter than this value are removed from the analysis. However, smaller fixations can also be interesting, as information are still seen by the respondent during the search process, though not fully elaborated. In this study, we analyse 2 different cut-off assumption: the standard convention to cut-off fixations shorter than 100ms, and a less restrictive cut-off of 50ms (Taller et al., 2016).

It is also found that the initial fixation activity is random, and tend to be at the center of the stimulus, as such this fixation should be removed. Krucien et al (2014) argued that the first and last fixations of each trial should be excluded because their position can be biased by the position of the fixation point (first fixation) or the decision to respond (last fixation). At the same time we can argue that even if random, if the fixation is long enough, that specific information is processed and can play a role in the decision process. In this work, we then decided not to remove the first fixation.

### 3. Data collection methodology

The SP experiment used in this work is based on a previous experiment that was built as a part of the Green eMotion (GeM), a European project that aimed at study individuals' preferences towards electric vehicle (EV) within several European countries (Jensen et al., 2014). The SP consists of a binary choice between an EV and an internal combustion vehicle (ICV), with the addition of a "no choice" option. The attributes that define each alternative are Purchase price, Driving costs, Operating range and CO2 emissions. Based on a vast literature, these are the attributes most significant in the choice of EVs, though not the only ones. Differently from the SP used in the Green eMotion project, we chose not to include the attributes related to the availability of different types of recharging infrastructure. There are two reasons that justify this choice. The first reason is that the measures of visual attentions are affected by the amount and complexity of the information provided. The recharging stations are complex information, they require more text to

be explained, and consequently a much longer time for the respondents to read and understand them. This effect was empirically observed in Cherchi and Raja (2016) who included the recharging infrastructures in their experiment. The second reason is that, as mentioned before, although important, recharging infrastructure are not the most important attributes in the choice of EV.

As in Cherchi and Raja (2016), we also chose to adopt a simple framework, trying to include the same number of information for all attributes presented. This, of course, reduces the realism of the experiment, but it gains in precision for the metrics computed from the eye tracker. Given the goal of this study, we chose to favour the eye tracker precision. An example of the choice tasks presented to respondents is illustrated in Figures 5 and 6 in Section 4.2.

The experiment was customised based on the type of vehicles that respondents intended to buy within the next five years or have recently bought (in the last five years). Respondents were also asked to indicate the range of prices for their next or past purchase, in order to ensure that the Purchase prices range displayed in the SP was realistic. Several screening information was collected to guarantee realism. In particular respondents needed to have a driving licence and have recently driven, they should typically drive less than 150 km a day, they had to live in an area where it is realistic to install recharging station at home, and live close to the main road network and/or city centre, as the goal was to ensure that they could easily access the public recharging stations available. It is important to mention that, although the specific attribute about recharging station was not included in the SP experiment, this information was provided at the beginning of the experiment, and respondents were also carefully selected to guarantee that the information provided was realistic for them.

A sample of 30 participants was randomly selected from members of a panel, trying also to match the gender balance. Respondents' age in the final sample ranges from 18 to 57 years old, the majority of the respondents live in household with 2 cars and on average 2.3 numbers. None of the respondents had an EV or participated previously in studies about EV.

The recordings were done with an X3-120 eye tracker with a sampling rate of 120Hz. The eye tracker was attached to a 28 inch DELL screen with an active screen size of 33.8 x 59.8 cm. The screen resolution as well as the stimuli were set to 1920x1080 and the participants were sitting approx. 50-70 cm away from the screen. Some participants moved during the recording and the initial distance was adjusted for their comfort. The data was presented, recorded and analysed with Tobii Studio 3.4.8.

## **4. Analysis of visual attention and decision process**

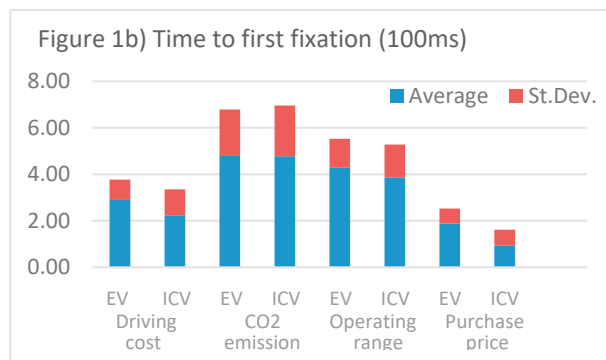
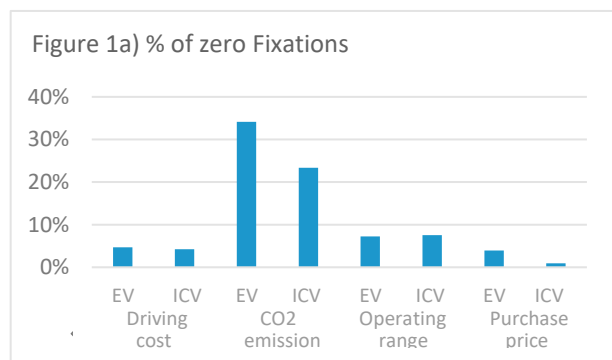
### *4.1. Attributes attendance*

As previously discussed, attributes non-attended represents one of the major concerns in SP experiments. It is considered that if a respondent has not looked at an attribute, he does not have processed it either. On the other hand, if a respondent looks at an attribute does not guarantee that he is processing it or that the attribute has a particular value. It is also important to remember that the attendance in the eye tracker experiment is defined up to a threshold, which can affect the definition of attendance.

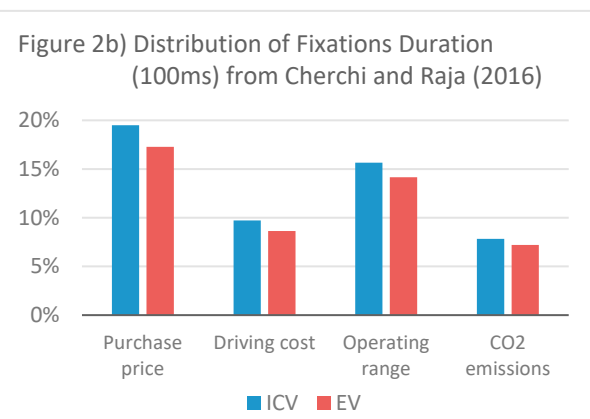
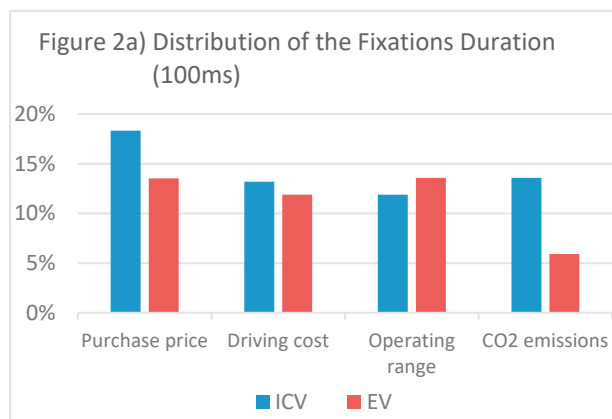
The number of attributes non-attended vary greatly among the different studies. Reasons can be related to the type of information provided in the SP experiment, the easiness of the respondents in processing this information, the relevancy of the attributes and the levels of the attributes presented in the choice tasks. Any comparison should then be taken careful. However, we note that some studies (e.g. Balcombe et al, 2015) found that most respondents visually attend most attributes most of the time and that none of the attributes is non-attended in the first choice task. In our study, we found instead that a high number of attributes were non-attended, some of them also in the first choice task.

Looking at the non-attendance distribution among the attributes (Figure 1a), the result seems to reflect the position of the attributes in the stimulus (Purchase Price ICV was on the top left and CO2 emission EV on the bottom right). This is confirmed also by the analysis of the time that it took to get the first fixation of each attribute (Figure 1b), which clearly shows that the Purchase Price ICV is the first attribute respondents looked at, while CO2 emissions the last one. At an aggregate level (i.e. across choice tasks and respondents), there is 87% of correlation between the number of zero fixations and the time that it takes to fix an attribute the first time. However, while this is true on average, there is a significant heterogeneity across the sample, with the standard deviation equal to half of the average for some attribute. More importantly, there is no correlation between the time to the first fixation and duration of the

fixation for each attribute. For example, we found a correlation of 0.03 between the time to first fixate the CO<sub>2</sub> emission EV attribute and the duration of the fixation, indicating that the position in the stimulus does not affect the visual attention, and that probably the less attendance of the emission reflects also the importance of the attributes. Interestingly we found that the number of zero fixations is stable across the six choice tasks.



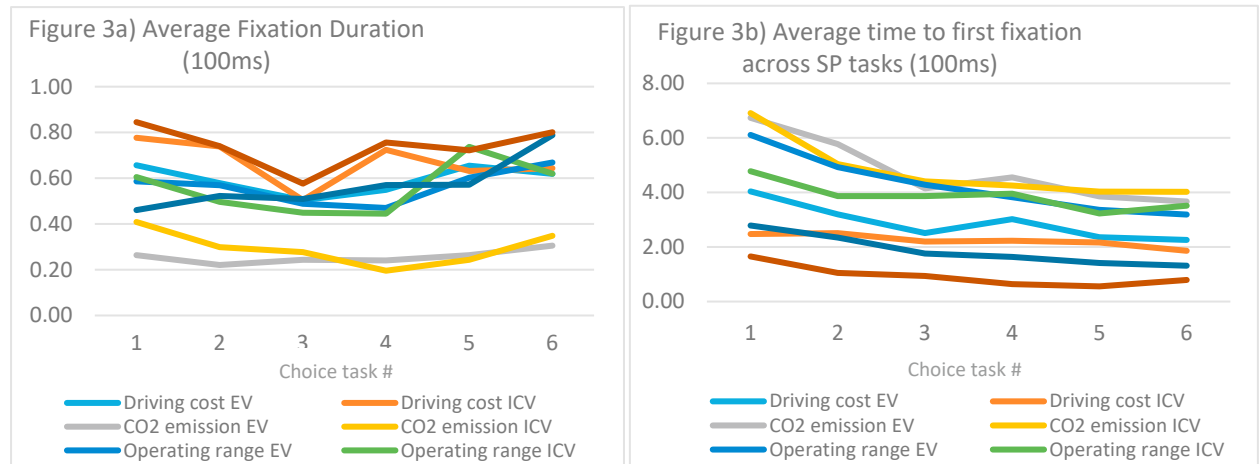
In terms of duration of the fixations, we found that overall respondents spend more or less the same amount of time in the common characteristics of ICV and EV, but there is a significant difference among attributes. Interestingly, the pattern is similar to the one observed in Cherchi and Raja (2016), and interestingly respondents fixate longer all the ICV attributes than the corresponding EV attributes (see Figure 2a and 2b). Since the EV is a new alternative, one would expect that respondents would have spent more time fixating the EV attributes, as they have to get to know the new alternative. It might be, however, that respondents look at the ICV alternative to first evaluate how distant this is from the ICV car they had in mind to buy, as this represents an easy and more direct comparison, before comparing it with the new EV alternative. If this is true, then we should probably re-think the SP designs for new products, at least those for EV.



Fixation time is typically found to decrease from the first to the last choice task presented, reflecting the experience gained by the respondents over the SP exercise. Interestingly in our experiment, we found that the time to the first fixation reduces of approximately 1/3 between the first and the sixth choice task (see Figure 3b) but the duration of the fixation does not (see Figure 3a). In particular, the duration of the fixation reduces along the first 3 tasks and then increases again. This is particularly evident for some attributes, such as the Purchase price ICV, but the trend is common to all attributes. The tasks were divided in 3 blocks and randomly assigned to respondents, hence the Purchase price level presented was not the same for all respondents. We checked the correlation between the levels of the Purchase price ICV and the duration of the fixation for the Purchase price ICV. Correlation is not small, but less than 50%. Moreover, the average Purchase price ICV presented increases from the first to the third task (up to 8% higher),

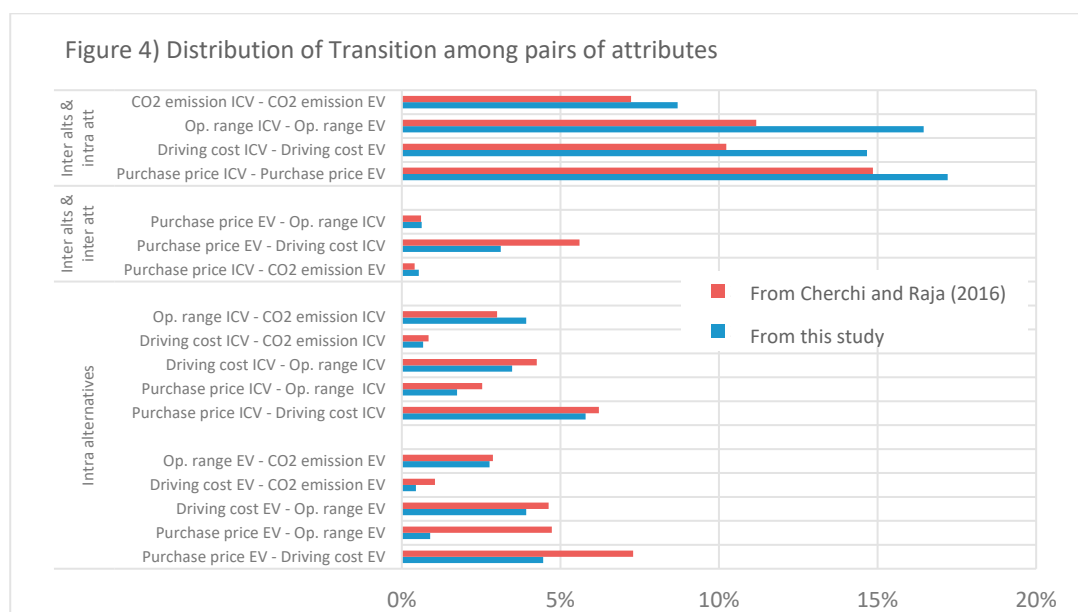
it decreases in task 4 and then increases again, confirming that there is no correlation between level of the attribute and the time it is fixated.

We repeated all these analysis for the number of fixations and the number and duration of the visits to the AOI and we found not significant differences. No significant difference was found also between the 100ms and 50ms cut-off.



#### 4.2. Transitions and trade-offs

The analysis of the transitions (Figure 4) is another interesting information that can be elicited from the eye tracker, as it informs on the pairs of attributes that each respondent looks at back and forth. This visual process hints to the presence of a trade-off between that pair of attributes. The analysis of the transitions in our study reveals that individuals mainly compared the same attribute between alternatives (inter-alternative trade-off), and in particular the Purchase price, followed by Operating range and Driving cost. The trade-offs intra alternatives, i.e. between attributes of the same alternative, is much less frequent and occurs mainly between Purchase price and Driving cost (probably because both are expressed in monetary value), and in line with the result about the fixation, transitions are more frequent within the ICV alternative than the EV alternative. It is interesting to note that the results of Cherchi and Raja (2016) shows a very similar pattern.





### 4.3. Heterogeneity in the individual decision process

The metrics discussed so far are particularly suitable to test the effect of visual attention in the estimation of individual preferences. However, they are not able to unfold the full and striking heterogeneity in the individual visual process. Balcombe et al. (2015) commented that they found a considerable degree of heterogeneity in behaviour while participating in the experiment in terms of number of fixation in each attribute. Our results confirm it. In addition to that, there is also a high heterogeneity in the number of attributes non-attended and in the sequence how the attributes are looking at. In this section we would like to draw the attention to the sequence of the attributes looked at, which can be visualised with the scan path. Figure 5a) and 5b) shows the scan path of two respondents for all the 6 choice tasks presented. Respondent in Figure 5a) seems to have an “ideal” decision process, she has a very regular and consistent scan path through all the tasks. She looks at all the attributes, with the attention strongly stable at the centre of the AOI.

Figure 5a) Example of heterogeneity in the scan path across respondents



Respondent in Figure 5b) shows a very different scan path. She definitely did not look at all the attributes, even in the very first choice task presented. The attributes non-attended are different among the 6 tasks. The focus is often in between AOI or outside the screen. If, in accordance with Krucien et al. (2014) we cut-off the first fixations, we can reasonably conclude that this respondent was not engaged in the exercise. As we will discuss later the inclusion of this respondent in the model estimation worsen significantly the results and it was indeed removed.

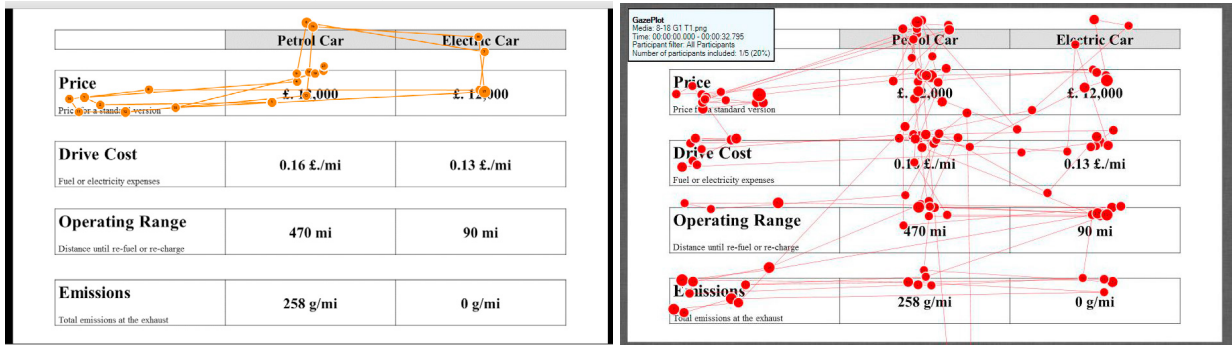
Figure 5b) - Example of heterogeneity in the scan path across respondents



These are just 2 examples, interesting because quite opposite, but they do not even cover the heterogeneity observed across the sample. To give a better idea of what we mean, Figure 6 reports two more examples of how other 2 other respondents looked at the first choice task presented.



Figure 6) - Example of heterogeneity in the scan path across respondents



While it seems straightforward to conclude that first respondent (the scan path on the left) is lexicographic in the price (at least in the first choice task), the second respondent (on the right) clearly looked at all the attributes quite carefully; however her decision strategy can still be different from compensatory.

#### 4.4. Relation between visual attention and preferences for attributes

To test if there is a relation between visual attention and preferences for specific attributes, discrete choice models were specified where the marginal utility of the attributes depended on the level of visual attentions. The utility took the form:

$$U_{jqt} = \sum_k \theta_{kj} X_{kjqt} \cdot FT_{kjqt} + \varepsilon_{jqt} + \mu_{jq} \quad (12)$$

Where  $X_{kjqt}$  are the attributes included in the SP experiment and  $FT_{kjqt}$  are measures of visual attention.

None of the visual attention measures proved to allow explaining better individual preferences for specific attributes. However, based on the analysis of the scan path we chose to eliminate 4 respondents, which proved to significantly improve model estimation. Unfortunately, for larger samples this “ad-hoc” analysis is not recommended and it is important to identify a metric to measure why individuals with those scan paths should be removed. The current metrics based on the fixations or non-attendance did not seem to be able to capture the full complexity of the link between visual process and decision process.

Since we observed that the first task, as expected, is the one where all respondents spent most time, we also tested a specification where we burned in the first task, i.e. we tested the effect of visual attention from the second task onward. Results however did not change.

Finally, since we observed significant heterogeneity among respondents in the time needed before taking a decision, we also tested a specification where, for each respondent, the visual attention measure for each attributes in each task was normalised by its average value across all attributes and tasks performed by the respondent. Results however did not improve significantly.

The transitions were tested in an analogous way, i.e. the inter-alternative intra-attributes transitions were interacted with corresponding attributes, but results did not improve either.

Finally, we estimated other two models where the utilities were specified considering only the visual attention measures, without the attributes of the SP experiment. Interestingly the transitions explained the choice similarly than the SP attributes, while the fixations did not.

## 5. Conclusions

This paper presents the results of a SP experiment conducted using an eye tracker device to measure how individuals process information while making the choice of the preferred alternatives. This work aimed to add some evidences to the current literature that is very promising but still too small and inconclusive. This research tried to

shed some light into the potential of the eye tracker measures to reveal the behavioural decision process. Our results reinforce the evidence that fixation is not a good (or probably not sufficient) measure to reveal the importance of the attribute. This is probably linked to the heterogeneity of the individual's visual process, and we found that the analysis of the scan path, i.e. of the sequence of the information fixated. Many more studies and validation tests are of course needed before some conclusion can be drawn. A bigger sample is also needed to get more robust modelling results.

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